FINAL TECHNICAL REPORT
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REPORT

PROPAGATION TRANSFER FUNCTIONS

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#2585

FINAL TECHNICAL REPORT

Propagation Transfer Functions

Title: Propagation Transfer Functions

Contract No.: F33657-69-C-1029

AFTAC Project Authorization: VELA T/9506/F/ASD

ARPA Order: 1371

Program Code: 9F20

Contractor: University of Denver

Effective Date of Contract: 12 March 1969

Contract Expiration Date: 30 June 1971

Principle Investigator and Project Scientist: Ross W. Buchanan

Phone Number: 303-753-2241

Contract Amount: $224,826

Period Reported: 1 July 1970 - 30 June 1971

\- Performed by -

Electronics Division
Denver Research Institute
University of Denver
Denver, Colorado 80210

15 September 1971

APPROVED BY:

Herbert Reno
Head, Electronics Division

PREPARED BY:

Ross W. Buchanan, Head
Field Operations & Special Projects Laboratory
Electronics Division

Gary G. Sanford
Research Engineer
Electronics Division

ACKNOWLEDGEMENTS

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by Headquarters, United States Air Force (AFTAC/NYDG), Washington, D.C. 20333 under Contract F33657-69-C-1029.

Pulse recordings required the use of a B-DOT loop sensor which was loaned to DRI by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico.

TABLE OF CONTENTS

I. SUMMARY

A. Authorization for the purchase of an EMP simulator was received, and project personnel were prepared for operating and maintaining the simulator. The manufacturer made a number of significant improvements in the design of the simulator. The unit was accepted without difficulty and delivered to the Cherry Creek Field Site. A failure occurred shortly after delivery, but the problem was corrected and the simulator has operated reliably since then.

B. The pulse from the simulator has been recorded using ground based and airborne instrumentation. Fourier analyses of the pulse waveforms have been computed. The waveforms for each configuration of the simulator have been repeatable in every case.

C. A system of horizontal radials was developed for a late time antenna. However, the design goal for the antenna was subsequently modified, and an extended cone was developed. This design was built and installed at the Cherry Creek Field Site. A secondary late time antenna was built in an attempt to generate a double pulse.

D. A cradle was fabricated to aid in the horizontal positioning of the pulser, and poles were set up to hoist the pulser while in the horizontal position.

E. A building has been planned which will provide shelter for the pulser during maintenance operations at the Cherry Creek Field Site.

II. DESCRIPTION OF WORK

A. Purchase of EMP Simulator

Approval for purchase of a Physics International 2.0 megavolt Pulser was received during the first quarter. The unit and accessories were to be delivered during the week of 4 January 1971.

Prior to delivery of the pulser two trips were made to benefit from the experience of other organizations in working with pulser systems. A one day visit was made to Kirtland Air Force Base during August. Contacts there were Captain H.B. Robbins and Sgt. Goodwyn. They both agreed with the decision to procure the pulser and a minimum of accessory equipment from P.I. They felt that DRI could follow the lead of the Air Force and Army in making any modifications as required in house. Then during the month of October, a visit to MERDC was made to gain experience in maintenance of the pulser unit. One of the MERDC units was undergoing complete overhaul while the other had trouble in the Marx unit which caused uncontrollable prefires. This was an excellent visit, and we were fortunate to be able to help with the overhaul as well as to help troubleshoot the operating unit.

The pulser acceptance tests were delayed one week due to design improvements by Physics International. These improvements are listed below:

1. Simplified capacitor mounting to allow single capacitor removal without complete Marx disassembly.
2. Improved Marx generator spark gap design.
3. Enclosed Marx generator spark gaps which allow better control of the Marx unit firing conditions.
4. Increased capacitor spacing to minimize capacitor to capacitor breakdown.
5. Improved seals on the copper sulphate resistors to prevent solution leakage.
6. Two view ports in the Marx unit housing for visual inspection.

7. Power supply in the sulfur hexafluoride atmosphere and mounted on the hinged Marx generator access lid for easy maintenance.

8. Remote control console for various pressure monitor gauges as well as charging and firing controls.

9. Set point meters for charge level and Marx charge unbalance.

10. Remote charging and unbalance indicators.

11. Low voltage gaps of the Marx unit triggered by midplane electrodes.

These improvements have provided a significant increase in the reliability of the pulser unit and were well worth the short additional wait for delivery. The pulser construction was of high quality throughout. The unit was accepted without difficulty at the Physics International plant during the week of January 4, 1971.

The pulser was delivered to the Cherry Creek Field Site. After its assembly it was installed on a temporary ground plane inside the fence perimeter. Shortly after initial testing had begun the pulser malfunctioned and it was determined that the lucite top of the water capacitor had been damaged by high voltage tracking. The problem was traced to the deionizer assembly for purification of the water in the water capacitor. The problem required major disassembly of the pulser. The damaged lucite part was taken to the DRI machine shop and the surface remachined to remove the high voltage tracking. All new materials (water, oil and deionizing compound) were used in the reassembly of the unit. After reassembly the unit functioned well and the preliminary tests were continued. One other problem was encountered with the unit. A small buss wire broke in the high voltage power supply. The wire connects AC and DC ground. No reason was found to cause the wire to break and no other damage was noted. The unit has operated without any other problems and has now been fired more than 700 times.

It is well worthy of note that all of the assembly repair and movement required have been accomplished by DRI personnel and AF/DRI assets. DRI purchased a motor driven crane for use at the Cherry Creek Field Site in this effort and it has proved to be invaluable and extremely cost effective.

B. Instrumentation and Preliminary Tests

One of the areas of prime importance is the transient recording system. Considerable effort has been expended in developing techniques for recording the pulse output at various azimuths, elevations, and distances with as much flexibility as possible. A screen box, Figure 1, has been made available for close in recordings, and a DRI screen room with adequate equipment space has been trailer mounted, as shown in Figure 2, for use at longer ranges. This trailer has a power generator and ventilation system for the screen room. DRI has not yet purchased sensors but has used those on loan from AFWL. Transient recordings of the pulse output were made at distances from 13 meters to 1 kilometer late in March.

In April, a temporary pad was set up to provide pulses for tests of the VHF and CALYPSO instruments using the pulser in a vertical position with only one early-time cone in place. By eliminating the lower cone, it was hoped that a monopole radiation pattern would result. The PI pulser was located on the concrete pad approximately 200 feet north of the perimeter fence at the Cherry Creek Field Site and was controlled from the north building. The transmitted pulse was monitored using the trailer mounted screen room for RFI shielding. The sensor used was an EG&G model MCL-2A, B-DOT loop. The signal was integrated with 1 microsecond integrators and recorded with a Tektronix 454 oscilloscope. The B-DOT loop was mounted at an elevation angle of approximately 1.5°, 2.6 meters above ground level at a point 100 meters from the pulse generator. This provided a reasonable record of the radiated

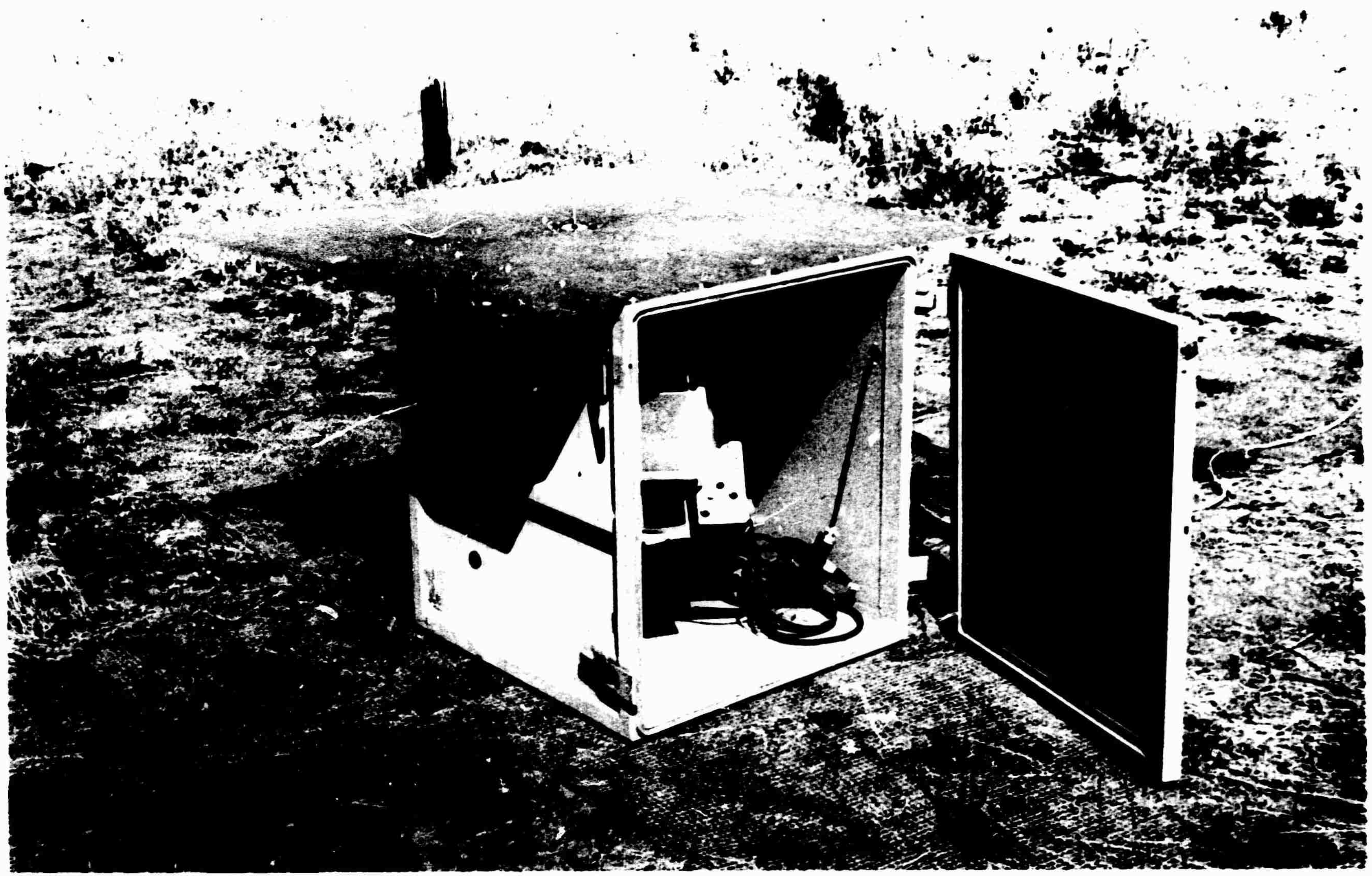


Figure 1. Screen Box for Recording Pulse

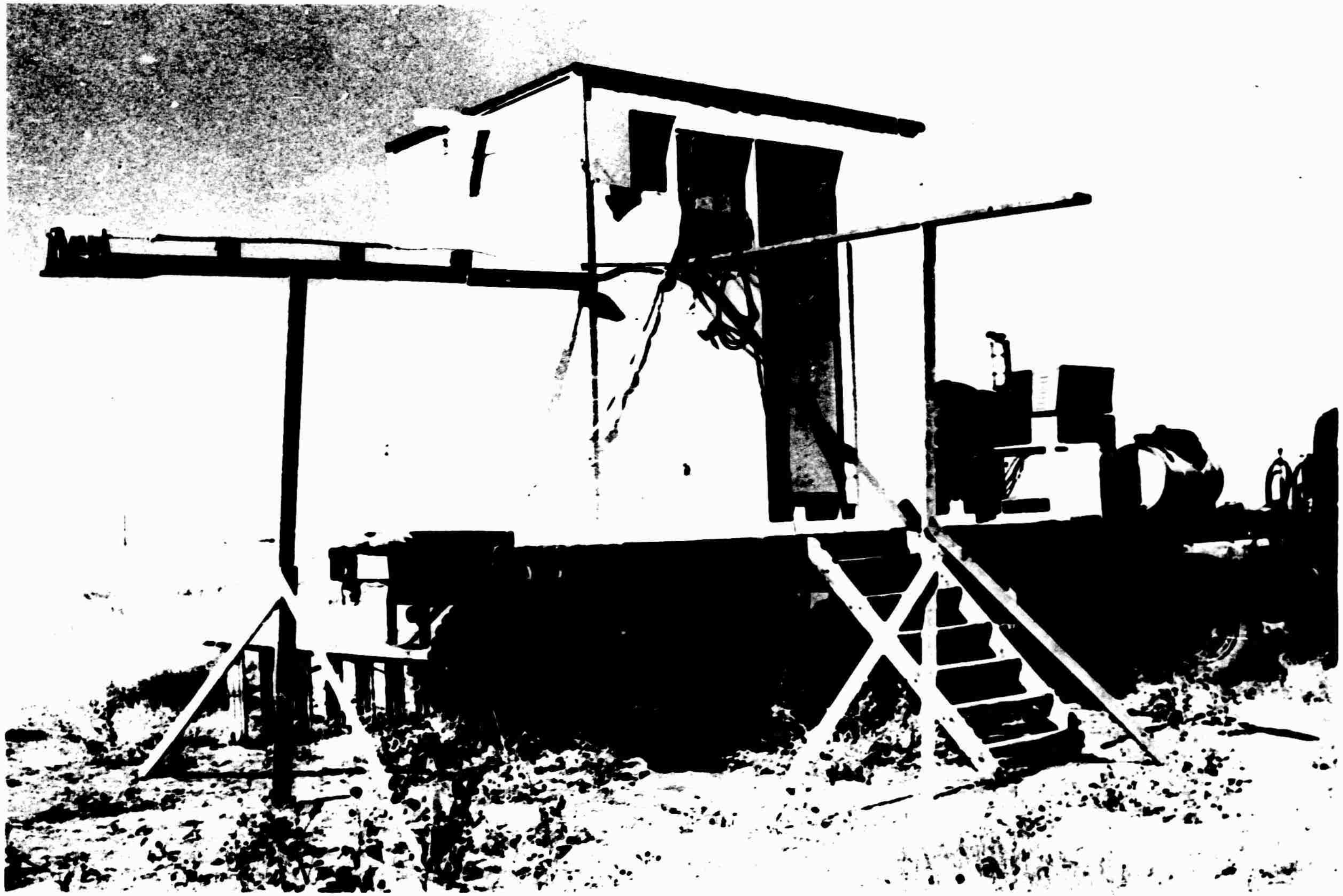


Figure 2. Trailer Mounted Screen Room

pulse at low elevation angles. One of the monitored pulses and its amplitude spectrum are shown in Figures 3 and 4 respectively. The pulse amplitude extrapolated to 1 km is 285 v/m and is in good agreement with the average extrapolated field strength of 268 v/m obtained from the scope #6 VHF recordings.

The recording equipment installed on platform 703 consisted of two full sets of VHF gear, each driven from a separate antenna, and one complete set of the CALYPSO II gear. The secondary normalizing channel trigger circuits of the two VHF systems were internally by-passed so that these channels could be triggered simultaneously with the primary normalizing channels. After the first hour of operation the CALYPSO system was operated in the internal trigger mode in an attempt to alleviate the difficulty in obtaining a reliable trigger pulse at the high threshold settings required because of local noise.

The pulser was fired approximately 70 times at 3 minute intervals during the operating period from 1820Z to 2030Z. Nearly all of the pulses were recorded with the VHF gear. Results were not as good with the CALYPSO II system which has a low frequency response that extends down to 300 kHz. The high level of local background noise in the broadcast band required higher trigger threshold settings than are normally used and at these settings the CALYPSO system did not trigger reliably on the PI pulse. However, six usable CALYPSO recordings were obtained during the run.

The pulse shape recorded throughout the experiment was remarkably stable and approximately independent of the platform elevation, heading, and azimuth. No obvious effects of platform distortion due to resonances or scattered fields are apparent in the recorded data. This observation is borne out by the amplitude spectra of six recordings from a VHF scope which are superimposed in Figure 5. The amplitudes shown have been extrapolated to a

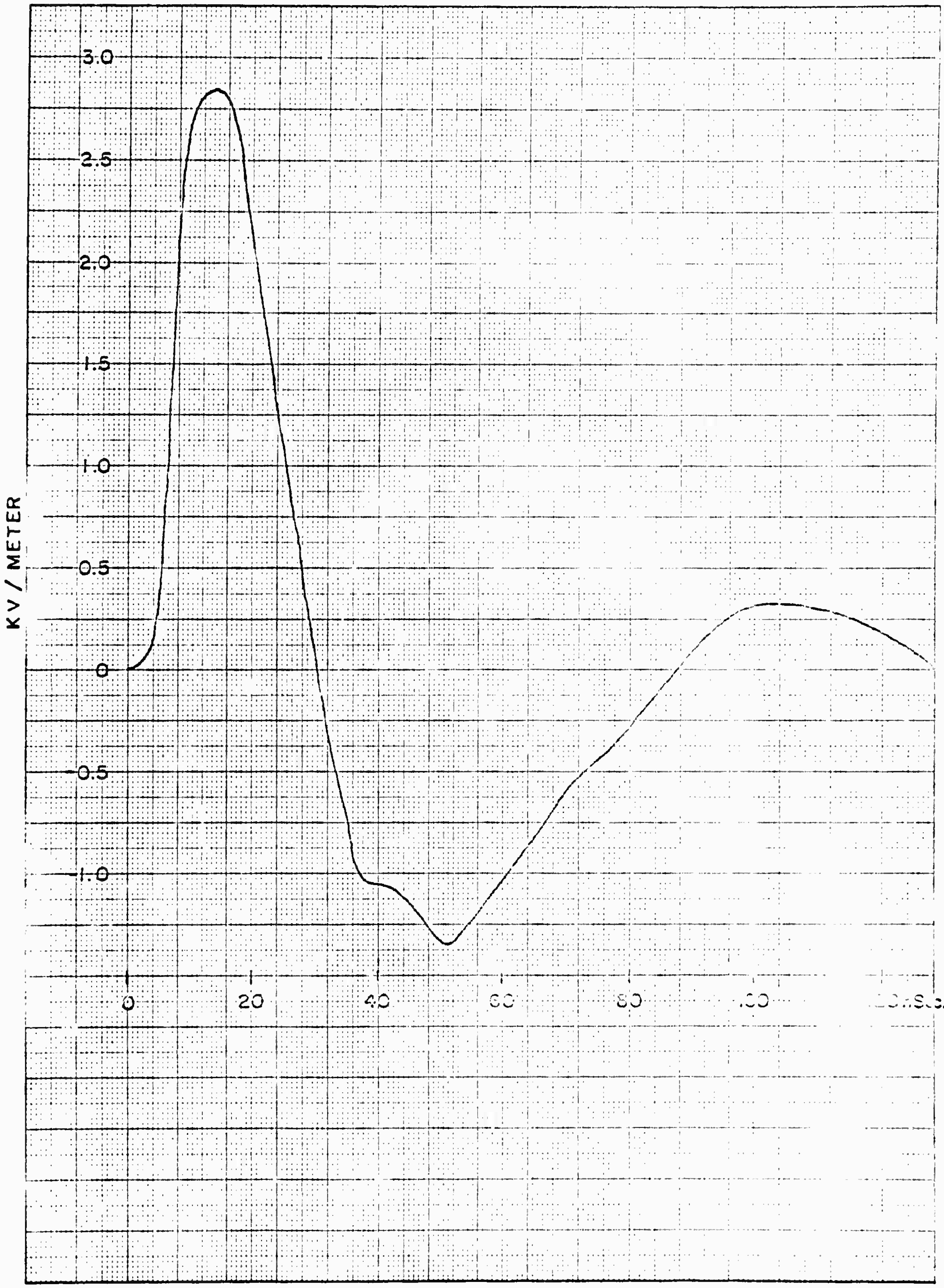


Figure 3. Vertically Polarized Pulse at 100 Meters - No Late Time Antenna

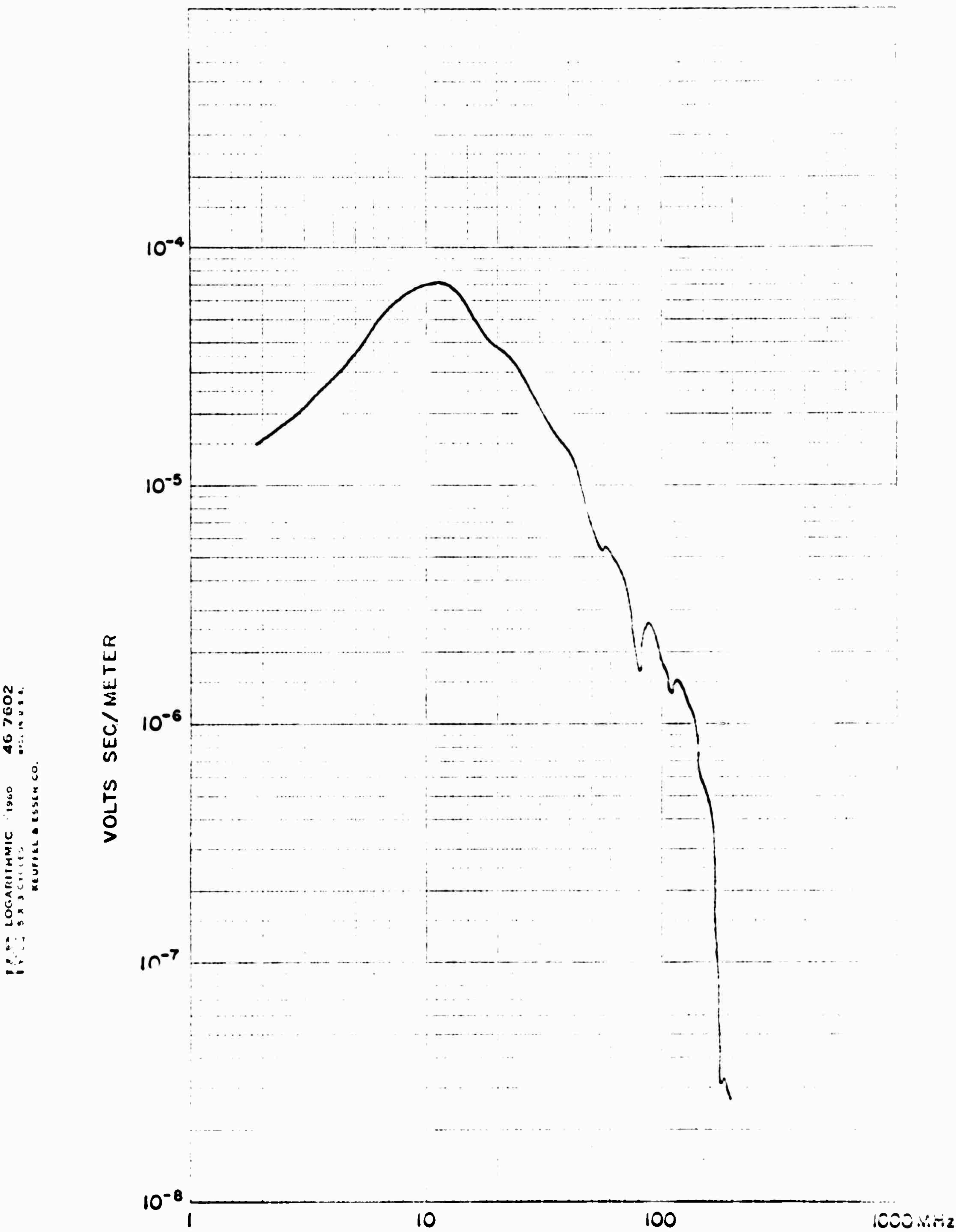


Figure 4. Spectrum of Vertically Polarized Pulse at 100 Meters - No Late Time Antenna

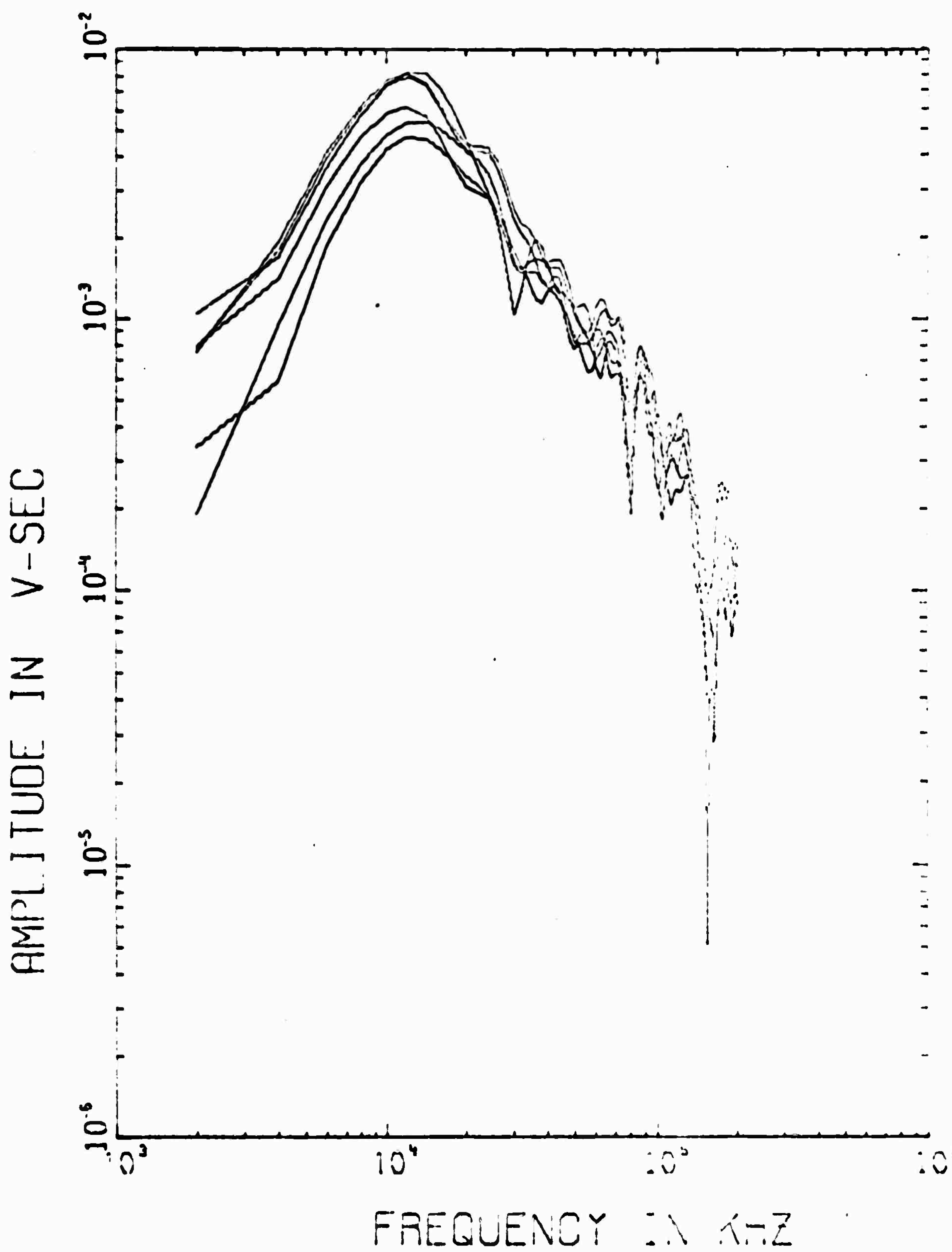


FIG. 5. AMPLITUDE SPECTRA FROM VHF SET #1, SCOPE # 1

distance of 1 meter by multiplying the pulse amplitude by the source-receiver distance. Two of the six spectra were calculated from waveforms radiated with the antenna in the double pulse configuration (See Section II C.), thus, they differ from the others at frequencies below approximately 25 MHz.

The tests provided the operating crew with a dry run under field operating conditions and also furnished information on the characteristics of the pulse radiated by the simulator that could only be obtained from an airborne receiver. Pulses were recorded at distances that varied from 6 to 150 km with corresponding elevation angles between 3° and 56°. A special technical note "Some Results Obtained Using the DRI Simulator During 703 Platform Field Tests on 18 April 1971," DRI #72-001, contains full details of these tests.

C. Vertical Late Time Antenna

The development of a late time antenna began before the delivery of the pulser. A quarter scale model of a vertical conical antenna was constructed but was found to be of little use in the study due to the high frequency reflections encountered. Therefore, a full scale antenna was built incorporating an early time cone (10 foot maximum diameter) and a 50 foot high vertical late time antenna. Using a simple capacitive discharge into the cone, a reliably repeatable pulse was produced. However, there was a reflection from the open circuit of the vertical late time antenna and it was decided to try a different late time configuration.

Using a set of 12 symmetrical 200' horizontal radials from the top of the cone and terminating each to ground with 12 Z_o (Z_o = the impedance of the conical antenna) pulse reflections were almost all eliminated. The pulse had a rise time of about 20 ns and a base width of about 45 ns. The spectrum of the pulse peaked between 6 to 10 MHz and was down 26 dB at 40 MHz. It was

clear that the pulse source did not have an adequate rise time.

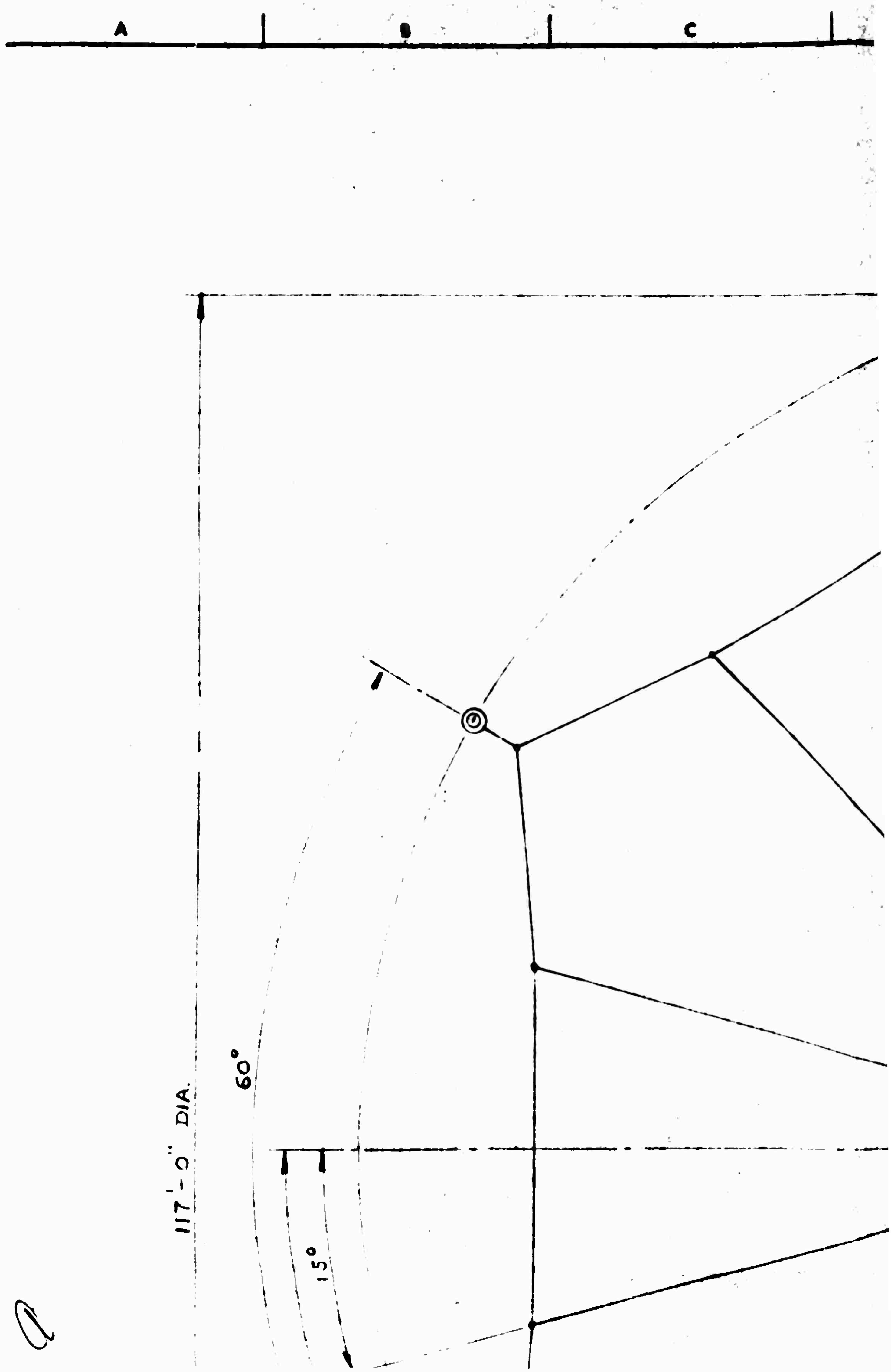
Accordingly a 6 stage Marx generator, inductor and matching transmission line were developed with existing DRI assets. The new source generated a pulse with a rise time of less than 2.4 ns (limit of the Tektronix 454 oscillorcope) and a width of about 10 ns. Again the use of horizontal radials proved to be most satisfactory for elimination of reflections. With the faster pulse it was possible to see the small reflections caused by the transition from the cone to the radials as well as reflections from the cone itself.

After the delivery of the pulser, the design goal of the late time antenna was modified by agreement of AFTAC and DRI. Further development of the horizontal radial antenna was delayed in order to develop a conical extension of the pulser cone that would provide maximum clear time for the radiated pulse. The design of the antenna was agreed upon after consultation with AFWL and is shown in Figure 6. The entire structure is rather large and considerable effort was expended to erect it as quickly as possible.

A 20 foot square concrete pad with a ground screen imbedded in it was built in the center of the area circled by six poles. These 100-foot poles were planted to support the wire structure of the late time antenna. Figure 7 is a photograph of the installation.

The pulser has been fired several hundred times in this configuration, including tests on DOY 195, 196-197, and 231 which were intended for reception by SRI in Hawaii and DRI at station 433. The pulse has always been repeatable as suggested by the typical pulse waveforms shown in Figure 8. The Fourier analysis of these pulses has been computed, and the resulting spectrum is shown in Figure 9.

A secondary late time antenna was built in an attempt to generate a double pulse. This was done by connecting a single feed wire to the top of a



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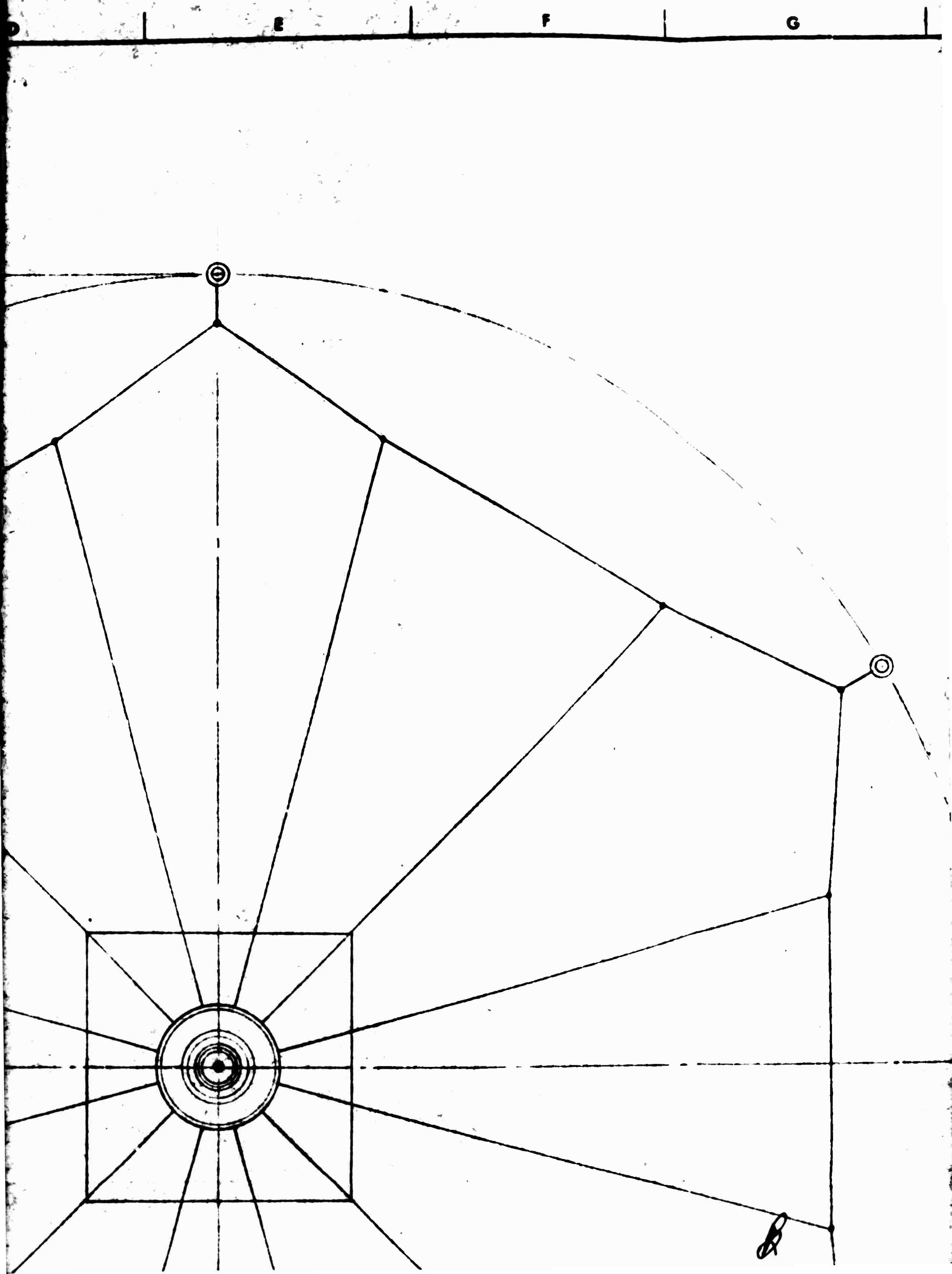
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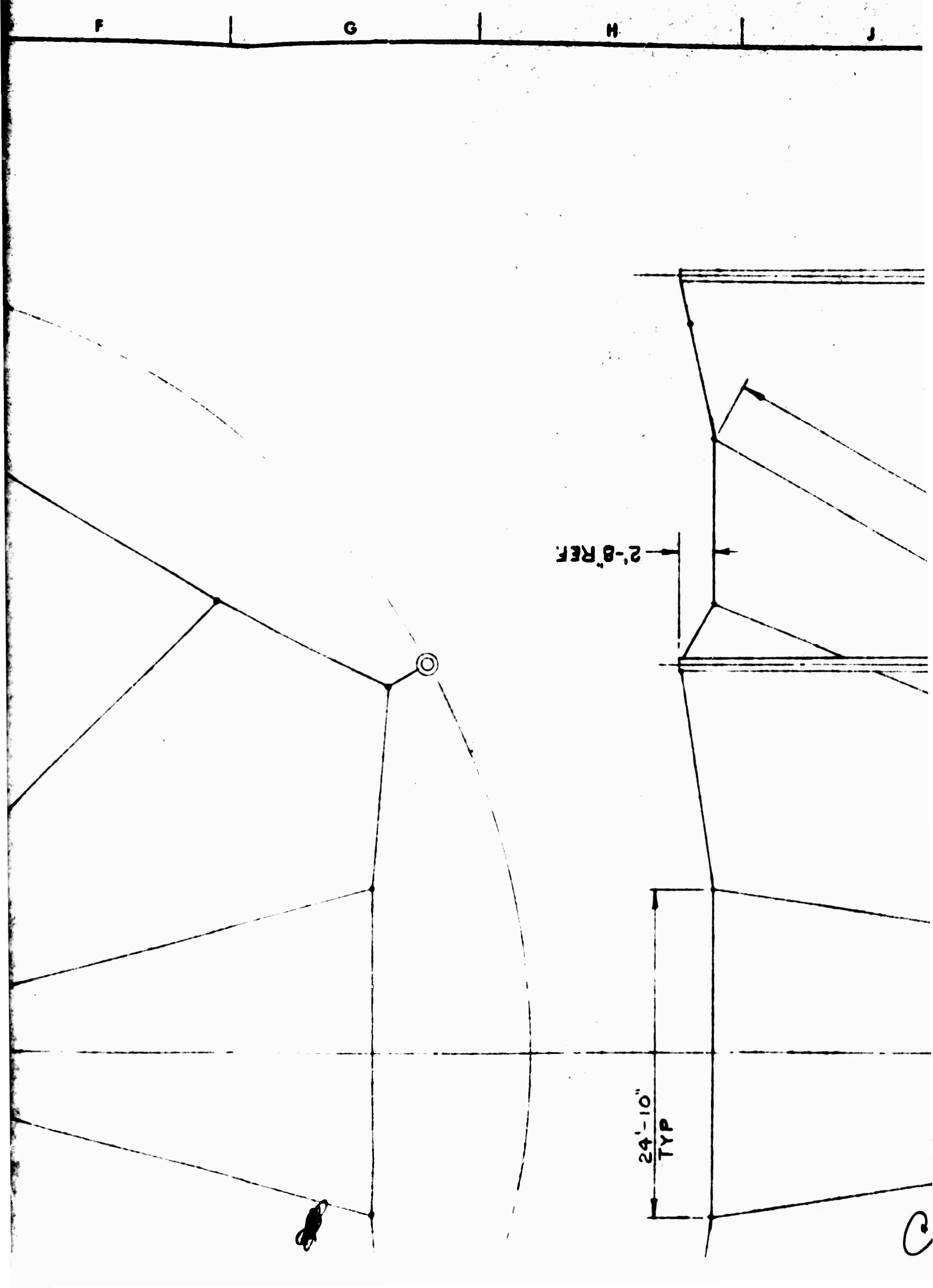

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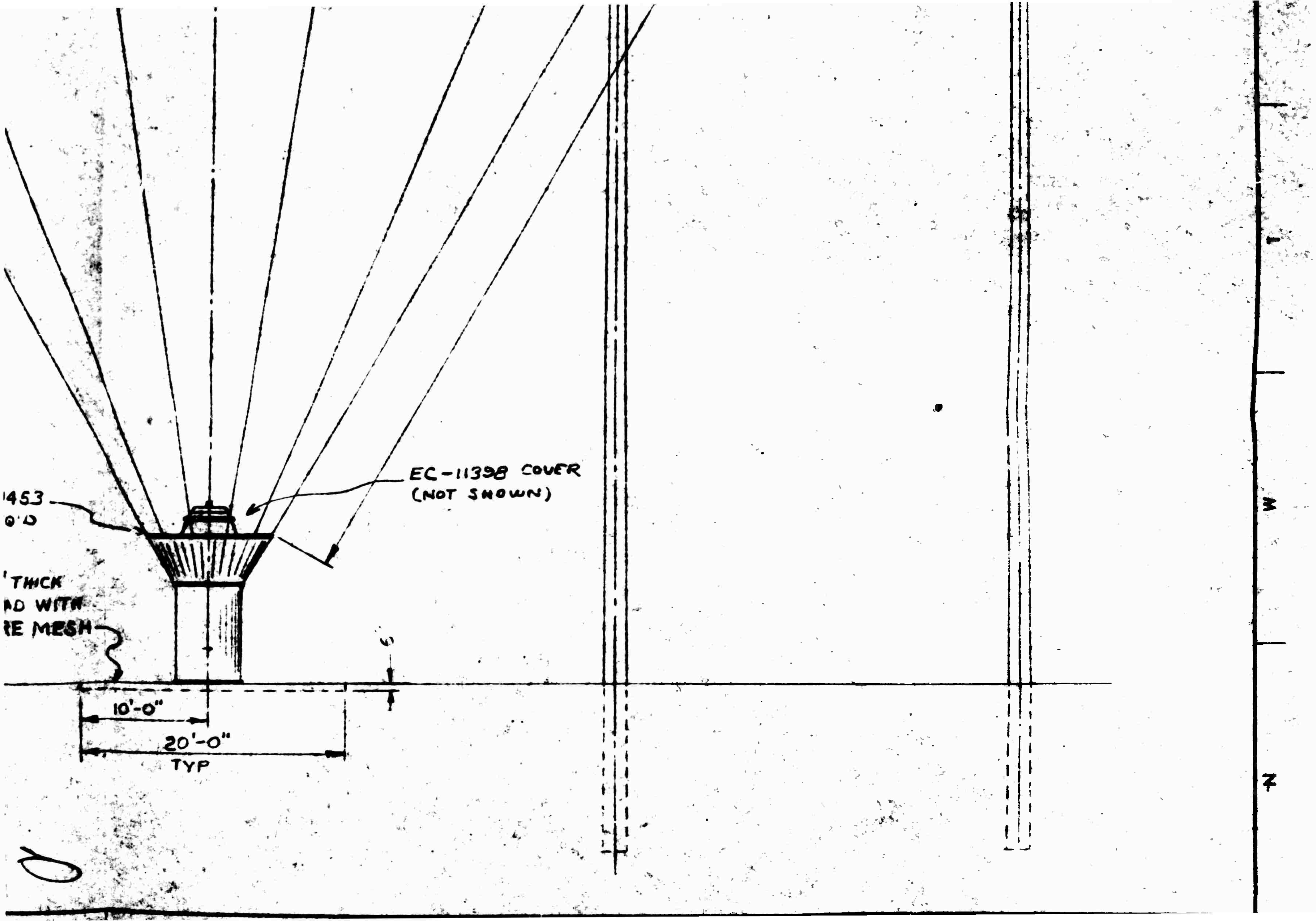
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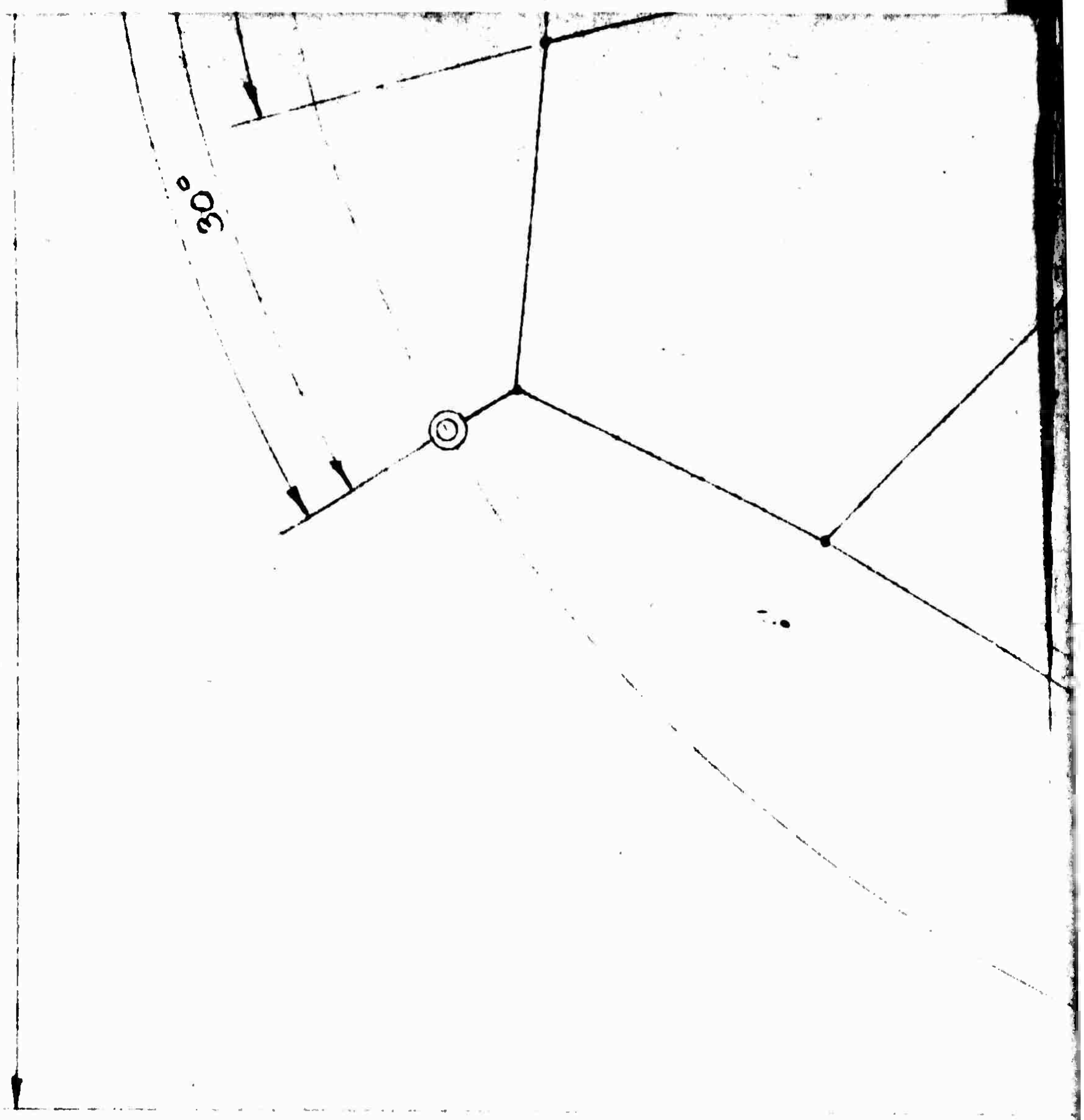

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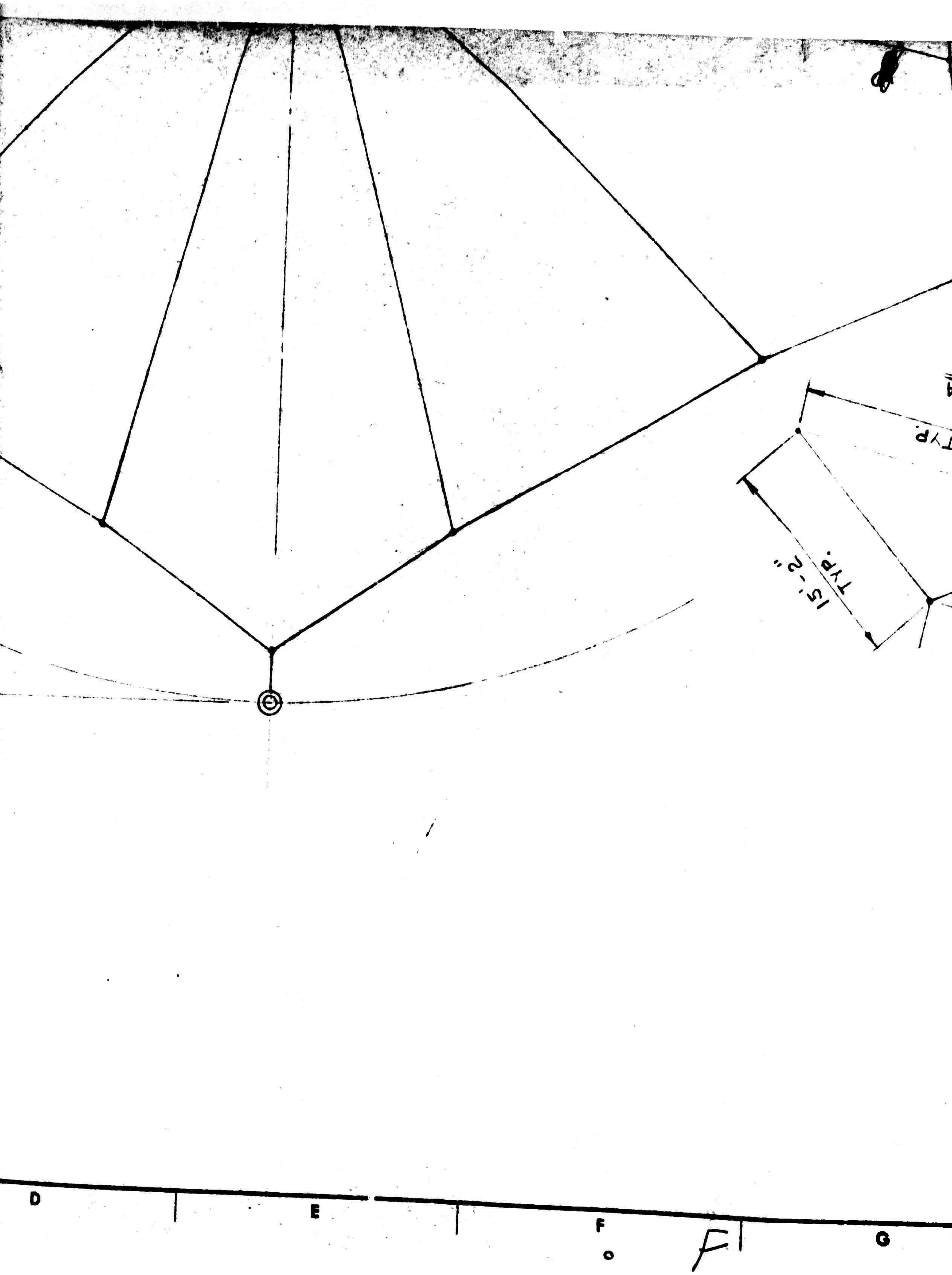
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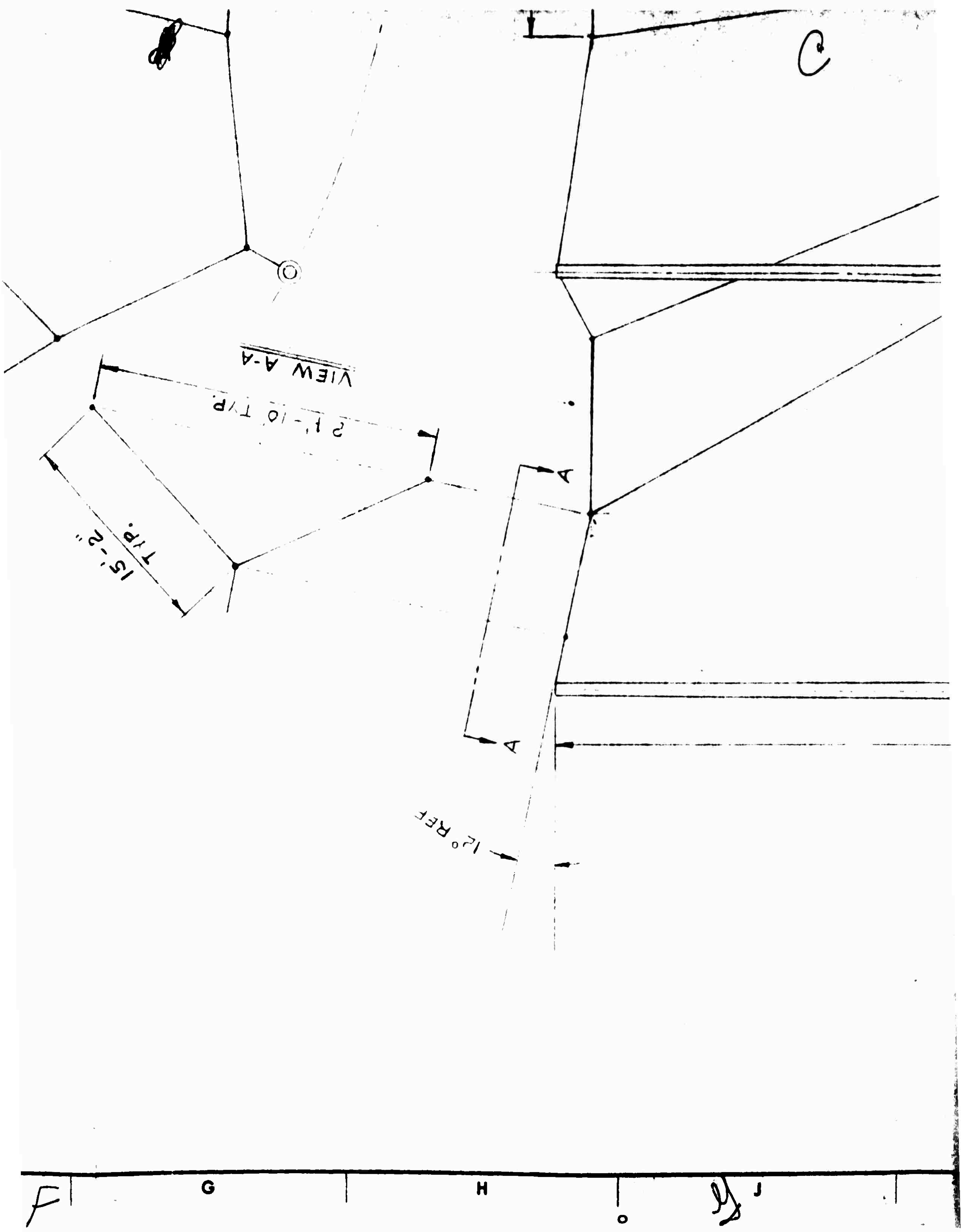

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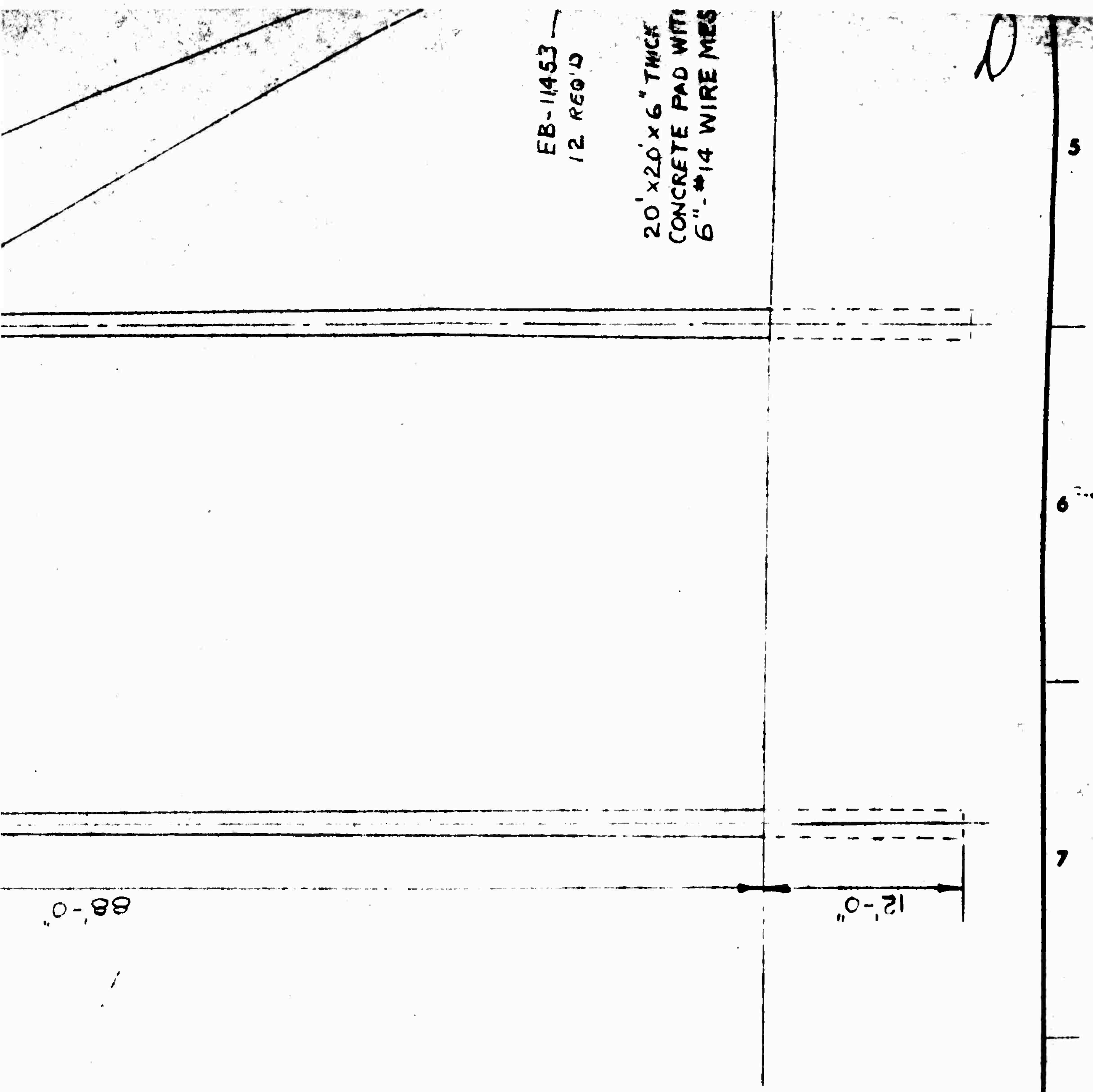

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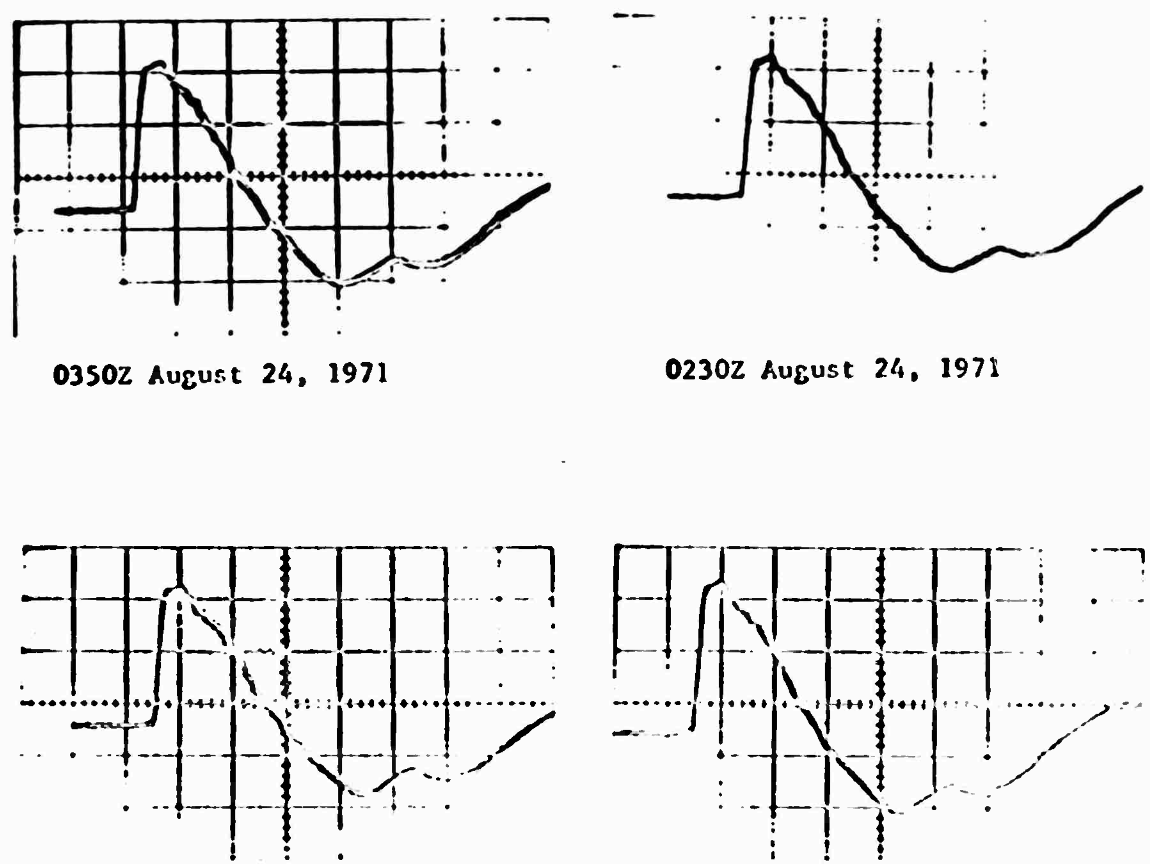
Figure 7. Late Time Antenna Installation

Horizontal Deflection
50 ns/division

Vertical deflection
1500 v/m/division



0350Z August 24, 1971

0230Z August 24, 1971

2320Z August 23, 1971

0510Z August 24, 1971

Figure 8. Typical Pulse Waveforms Transmitted with Large Vertical Antenna

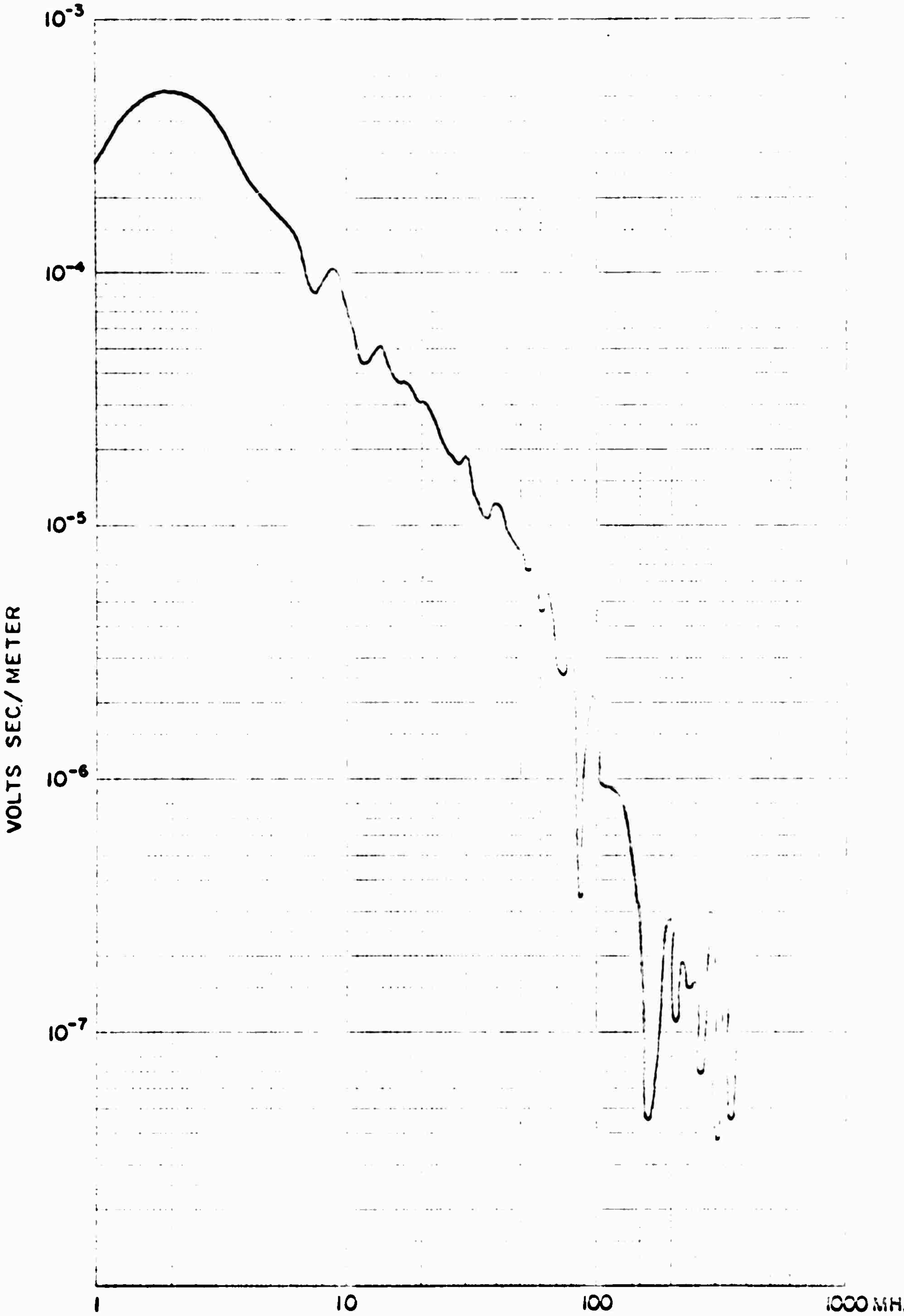


Figure 9. Spectrum of Pulse Transmitted with Large Vertical Antenna

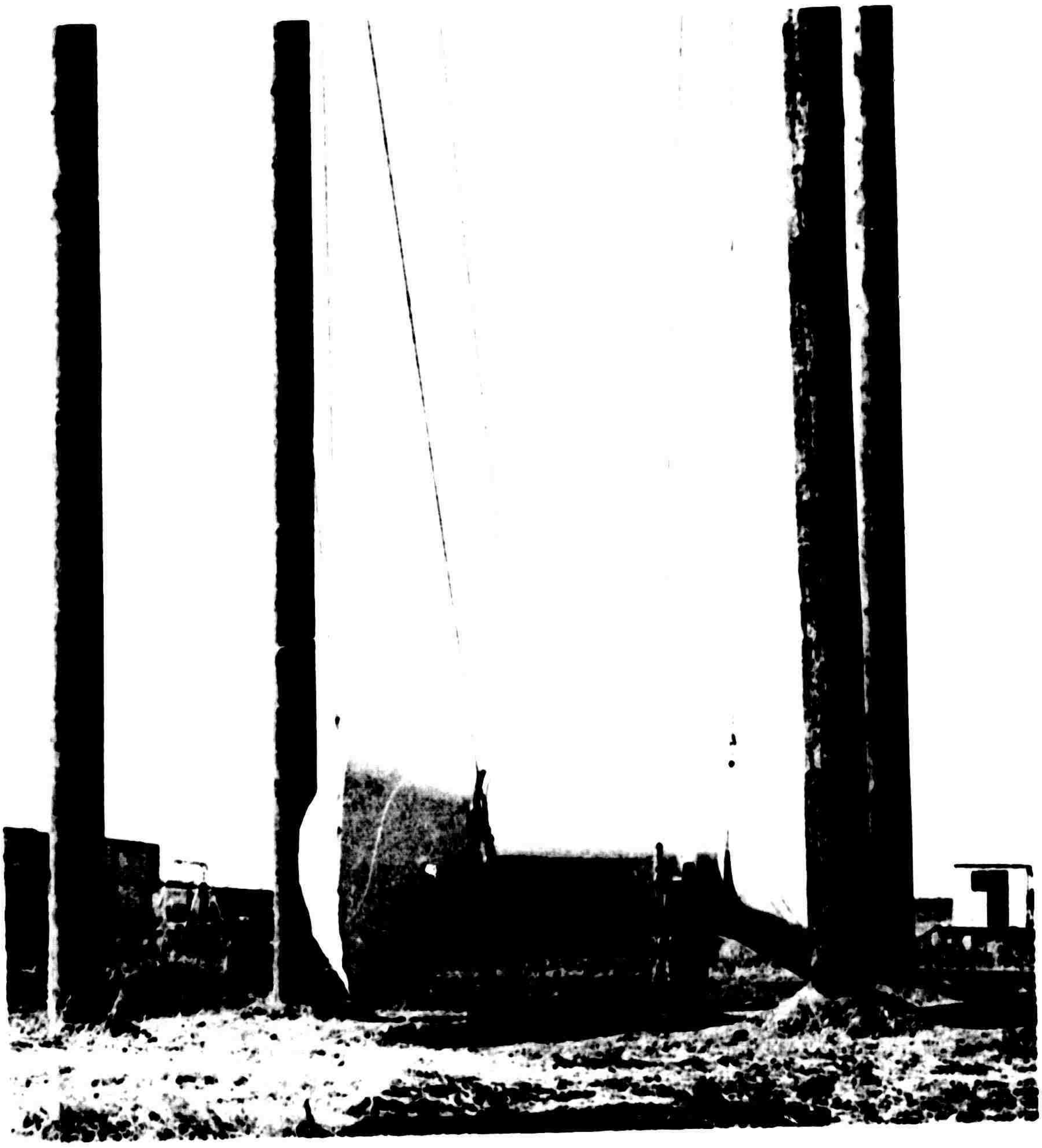


Figure 10. Pole Configuration for Horizontal Signal

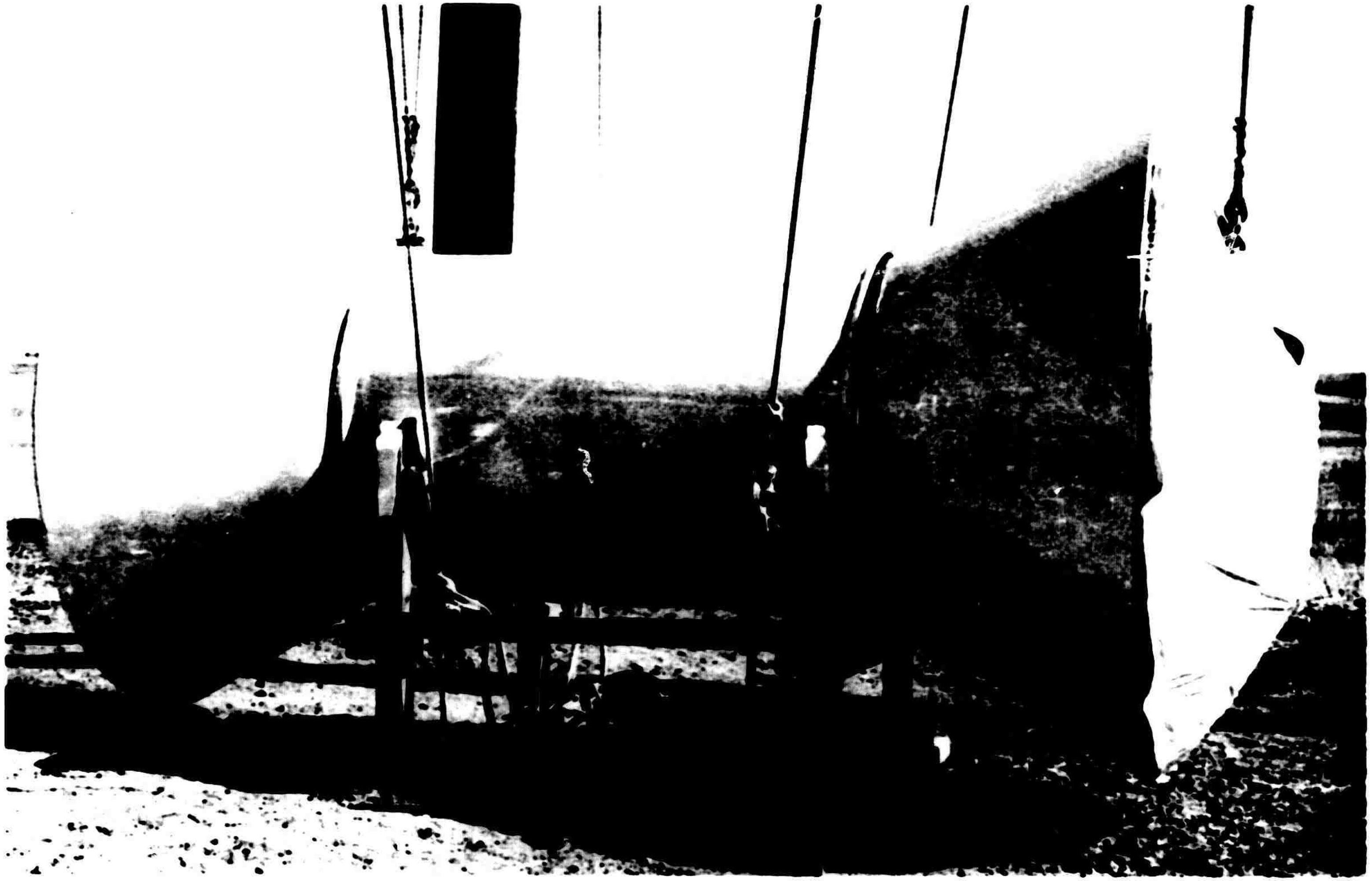


Figure 11. Pulser in Cradle

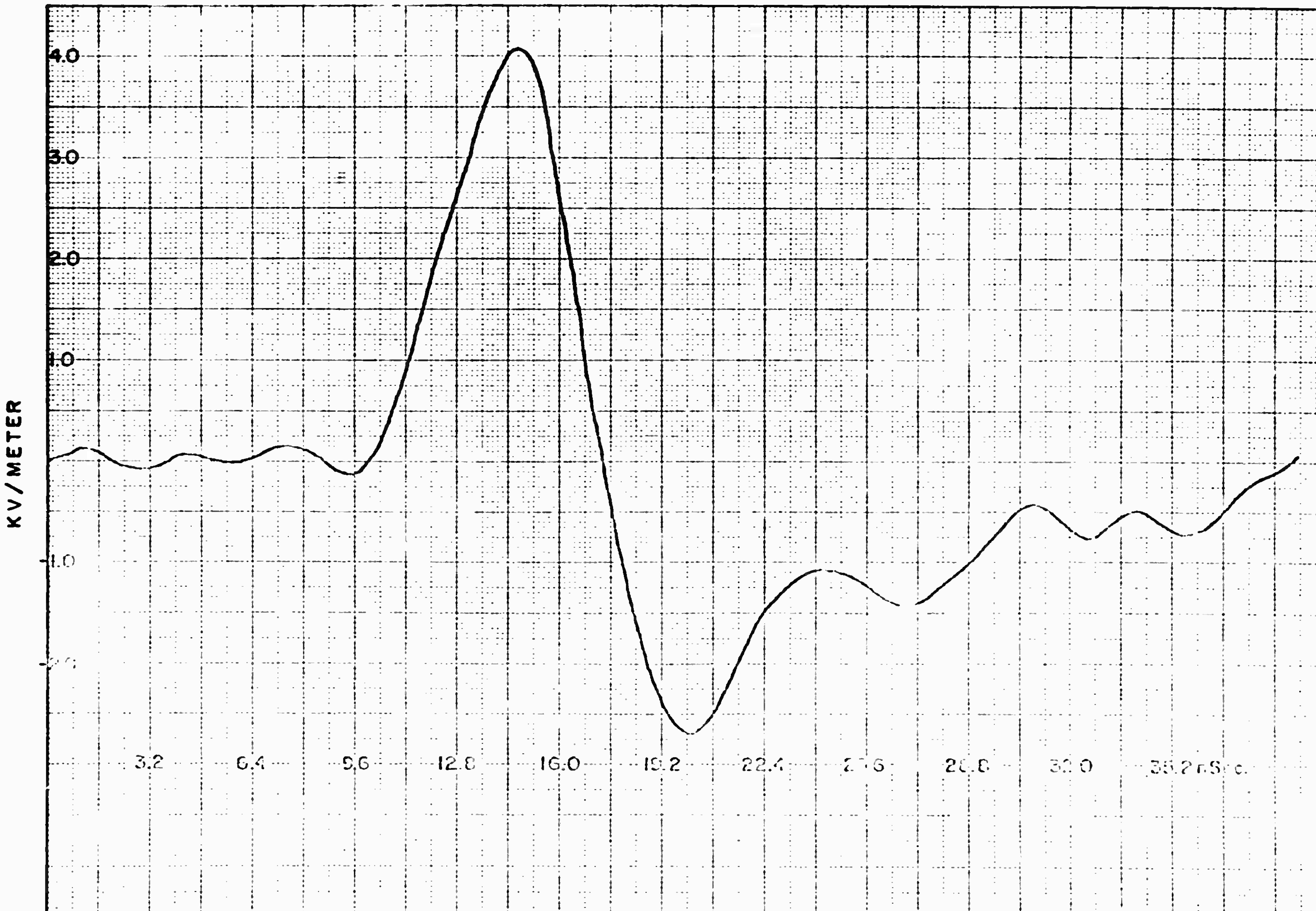


Figure 12. Horizontally Polarized Pulse at 100 Meters

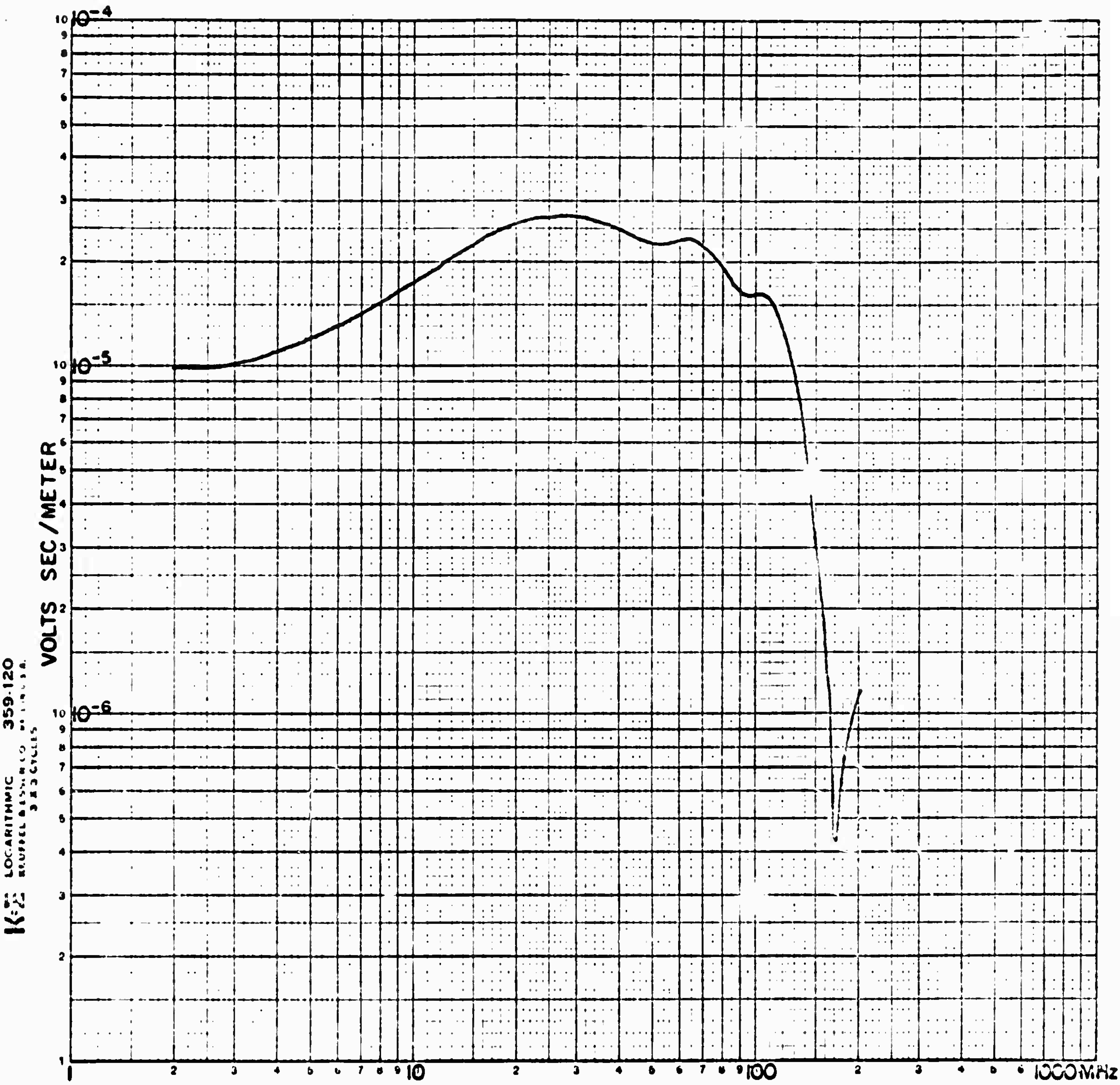


Figure 13. Spectrum of Horizontally Polarized Pulse at 100 Meters

useful for the construction of a fence around the pulser.

A building has been planned which will provide a shelter for the pulser during maintenance operations.

III. CONCLUSIONS

The pulser appears to be a well built improved RES unit. The problems encountered were easily solved, and the unit has operated reliably since then. The repeatability of the radiated pulse has been found excellent.

A pulse recording capability now exists and can be used to provide pulse output information as required. Present data are based on the assumption that the electrical characteristics of the B-DOT loop are determined entirely by its physical dimensions and therefore the loop is assured to be intrinsically calibrated. However, further effort is needed in the study of the loop antenna monitoring scheme to determine the accuracy with which the radiated free space field can be recorded and to determine what modifications in pulse shape, if any, arise from propagation effects and the sensor. In addition there should be a greater effort to define the pulse at higher elevation angles. Once these problems have been resolved it will be feasible to use the EMP simulator experimentally to determine system response functions with assured accuracy and reliability.

IV. FUTURE PLANS

The progress reported herein completes all the effort anticipated on the present contract. It is expected that more detailed calibration techniques will be applied, that the pulse waveform at higher elevations will be measured, that propagation studies will be undertaken and that a double-pulse concept will be tried when further funding is made available.